Project 5: "Reducing Freeway Emission via Ramp Metering Control"

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Project Summary

Increased traffic congestion and associated vehicle emissions impact ambient air quality and thus the health of drivers and urban dwellers. One essential question accordingly emerges regarding effective measures to mitigate freeway congestion. A practical solution to freeway congestion is the ramp metering system that controls vehicles entering into the freeway from an on ramp. The challenge facing this strategy is how "to ensure the design of ramp metering system effective to mitigating congestion while reducing vehicle emission?" As shown by **Figure 1**, by controlling the entering rate, the traffic flow in the freeway will remain at a moderate level of service and capacity due to the reduction of interrupted traffic from the ramp. At the same time, it is also expected to reduce vehicle emission, crashes and travel time as well, which in reality greatly improve the quality of people's daily life.

The project goal is to help the teachers to gain hands-on experience in understanding the mechanism about the operational and emission impact of ramp metering by learning related math modeling and simulation-based analysis of a real-world freeway (**Figure 1**). The result will help increase teachers' awareness of tying math and science knowledge with a real-world problem-solving strategy in addressing

a freeway congestion issue. The microscopic traffic simulation tool, VISSIM, and environmental analysis tool, MOVES, will be introduced to the teachers. The microscopic traffic simulation tools stimulate movements and interactions of road users through car-following and lane-changing algorithms. MOVES estimates on-road vehicle emissions given quantified transportation activities and attributes describing the physical and environmental features of the roadway infrastructures. These tools provide a cost-effective way to test the effect of traffic control measures, including the ramp metering system.

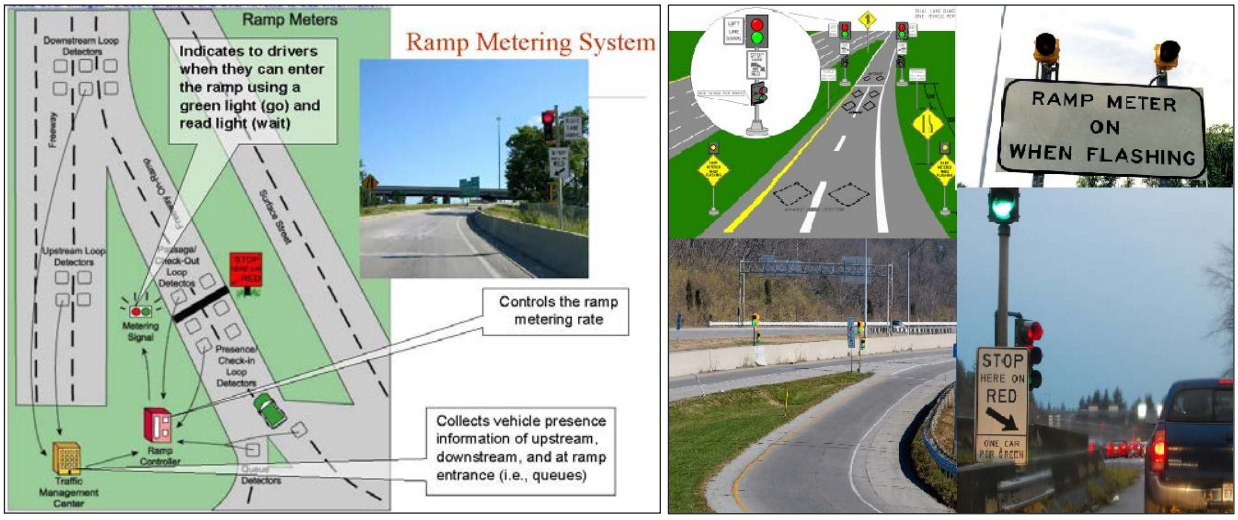

Figure 1: Illustration of Ramp Metering Operation (left) and Simulated System (right)

Meanwhile, the teachers will gain hand-on experience in using a sensor that measures Particulate Matters diameters of 2.5 micrometers or less (i.e., PM2.5) or Nitrogen Dioxide (NO2). Figure 2 shows examples of the PM2.5 and NO2 sensors, as well as GPS travel logger. The analysis of the near-road PM2.5 or NO2 data to be collected along with GPS-based traffic data expects authentic learning and understanding of how traffic situation impact vehicle emission. These pollutants can adversely affect health, and can also vary significantly dependent on the location and pollutant sources.

Figure 2: Illustration of PM2.5 and NO2 Sensor and GPS Data Logger

The research tasks will be completed in 7 weeks, including the following activities that are specifically designated for the 2015 summer project:

Week 1: The teachers will be taking an *Engineering Foundations* course along with other groups of teachers involved in the summer project.

Week 2: The teachers will participate in the training course for basics of ramp metering, analysis methods, and development of research framework. A real simulation example with use of VISSIM and MOVES, which will be adopted from an on-going EPA project, will be showcased to the teachers.

Week 3: Collection of GPS travel and PM2.5 or NO2 monitoring data, and relevant data analysis will be conducted under the supervision of the graduate student mentors.

Weeks 4-5: The teachers will leverage the last year's RET teachers' efforts in building a ramp metering system at the case study site in the VISSIM environment and learn how to reduce vehicle emission from freeway traffic by using the ramp metering system through simulation. Associated math and scientific principles involved in traffic operation and control will be reviewed in conjunction with the analysis result from Week 3.

Week 6: The teachers will compile the results and knowledge gained from the above tasks to develop their future classroom teaching improvement and implementation plan. Specifically they will develop the engineering design process activity to incorporate in their

Week 7: The teachers will be preparing final presentation, final report, and summary.

In addition, a field trip will be arranged to visit the statewide traffic management center (TMC) in Ohio Department of Transportation Center Office in Columbus, Ohio (**Figure 3**). This trip is expected to provide an authentic environment for the teachers to perceive the real-world traffic operation and management.

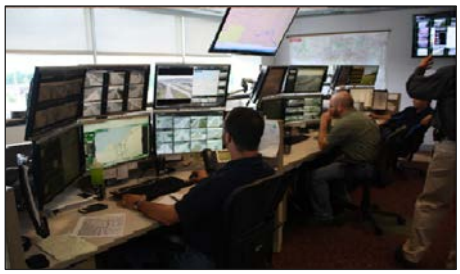

Figure 3: TMC in Columbus, Ohio

<u>Possible Ideas for Classroom Implementation</u>

The teachers could develop a classroom implementation plan around the theme of *"Math: how does it work on real-world problems?"* The course will help students understand the importance of math and science to address a societal problem through a case study of ramp metering impact analysis and assessment. It will use math to: estimate the design parameters using field collected experimental data; make inferences about the relationship between the parameters; conduct further data analysis to better understand the traffic condition of a freeway for ramp metering operation; understand PM2.5 or NO2 pollutant exposure level to commuters; and finally understand the emission reduction due to control measures. Thus, students will learn the freeway operations through the usage of math and scientific methods.